Design of Dual-Band Dual-Polarized Swastika-Shaped Antenna for Mobile Communication Base Stations

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***Abstract*—This paper proposes a new swastika-shaped design with dual-band dual-polarization for mobile communication base stations. The design consists of two orthogonal compact cross-dipoles printed on both sides of an FR4 substrate forming a swastika shape. The main advantage of this design is that it covers two frequency bands from 700-960 MHz and from 1.7-2.7 GHz simultaneously with reflection coefficients smaller than -10 dB. The isolation between ports is better than 26 dB. The radiation pattern is stable within each frequency band and of a high cross polarization discrimination ratio. The proposed design is much simpler than designs introduced in the literature as it uses a single element to cover both bands instead of using two different elements for these two bands. It also has a wider bandwidth which makes this new design a good candidate for dual-band mobile base station antennas.**

***Index Terms*—Base station anetnna, dual-band antenna, dual-polarized antenna, swastika-shaped dipoles.**

I. Introduction

The evolution of smart phone technology has resulted in the development of base station antennas for mobile communication systems from single-polarized to dual-polarized and from single band to dual or multi bands [1]. The most common frequency bands used for mobile communication systems are the lower band (LB) from about 700-960 MHz and the upper band (UB) from 1.7-2.7 GHz. For a higher data rate, space diversity and/or polarization diversity are commonly used [2]. The base station antenna designers face many challenges such as to obtain a stable radiation patterns within the desired frequency bands, high cross polarization discrimination ratios (XPD) and good impedance matching at the same time [3]. It is favorable to have a low cost deign with a small size as well.

Many successful designs have been introduced in the literature to meet these specifications for a single band antenna (either the LB or the UB) using planar cross dipoles [4] or 3D-printed dipoles [5][6]. The most challenging is to get a compact design which covers dual or multi bands. In [7], a dual-band antenna array is designed using two different collocated elements to cover two bands, an arc-probe-fed ring antenna for the LB and a printed microstrip dipole antenna for the UB. Moreover, in [8], two 3D pairs of cross-dipoles are used to widen the bandwidth (one pair for each band). Again they are collocated to reduce the antenna size. Later on, multi-band arrays have been achieved using three or more different frequency band elements with embedded scheme [9] or optimal array structure [10].

In this paper, a new swastika-shaped antenna design is introduced to cover both the LB and the UB simultaneously. To the best of the authors' knowledge, a single element which is able to cover both bands has not been introduced in the literature. The design enjoys a good impedance matching, stable radiation patterns within the frequency bands and high XPD with low cost and a compact size.

This paper is organized as follows: Section II discusses the element structure and the working principle. Section III illustrates the simulated results and some conclusions are presented in Section IV

II. Swastika-Shaped Antenna Element

A. Antenna Structure

Fig 1 illustrates the geometry of the antenna while TABLE I gives the dimensional parameters. Generally, the antenna can be described as two orthogonal ±45° dipoles with respect to X and Y-axes for polarization diversity. Each dipole is printed on one side of a square FR4 substrate with a relative dielectric constant ε_r= 4.3, tangential loss of 0.025, thickness of 1.6 mm and side length Ld. Each dipole has two elliptical-shaped poles which are linked with a strip line and a feeding connector.

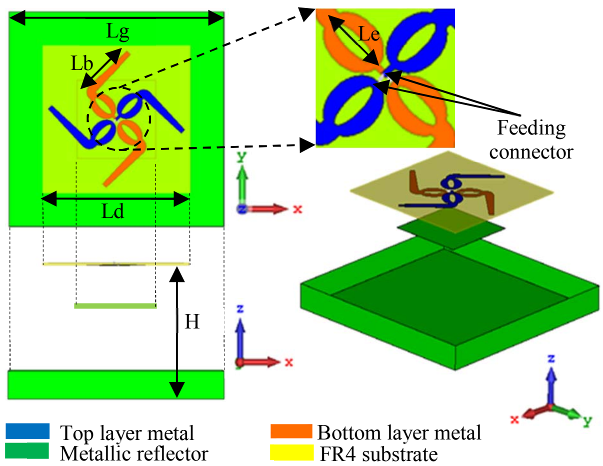


Fig 1. Geometry of the proposed antenna

TABLE I Parameters of the Proposed Antenna

Parameter	Value (mm)
Le	29
Lb	52
Ld	150
Lg	220
H	100

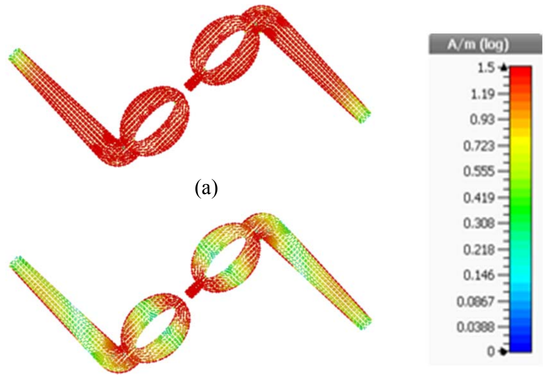
The end points of the elliptical-shaped dipoles are linked to bowtie dipoles which have right angle with respect to the elliptical-shaped dipoles forming a swastika shape. So, again bowtie dipoles have ±45° with respect to X and Y-axes. For a unidirectional radiation, the substrate is placed above two metallic square reflector planes: a small reflector and a large reflector for the UB and LB unidirectional radiations respectively. The large reflector has four sidewalls to improve the XPD. The substrate and the two metallic reflector planes are concentric and their edges are parallel to X and Y-axes.

B. *Antenna Working Principles*

The antenna design can be considered as two different types of dipoles connected together: bowtie dipoles and elliptical-shaped dipoles. Fig 2 presents the current distributions at the center frequency of each band (830 MHz for the LB and 2.2 GHz for the UB). At the LB, both types of dipoles (bowtie and elliptical) work together to form a half wavelength dipole with a total length equals to 2(Lb+Le). So, the current in this case is distributed from the feeding points to the bowtie dipole end points. At the UB, the elliptical dipole only works as a half wavelength dipole with a length of 2Le. So, the current distribution is highly dense on the elliptical surface and edges while bowtie dipole has a low current distribution.

III. SIMULATION AND RESULTS

The proposed antenna has been designed and simulated using CST microwave studio. Fig 3 illustrates the reflection coefficient (S11) and the transmission coefficient (S21) between the ports. The reflection coefficient is less than -10 dB for both bands while the isolation between ports is better than 28 dB and 26 dB for the LB and the UB respectively.



(a)

(b)

Fig 2. Current distribution at central frequencies of (a) LB (b) UB

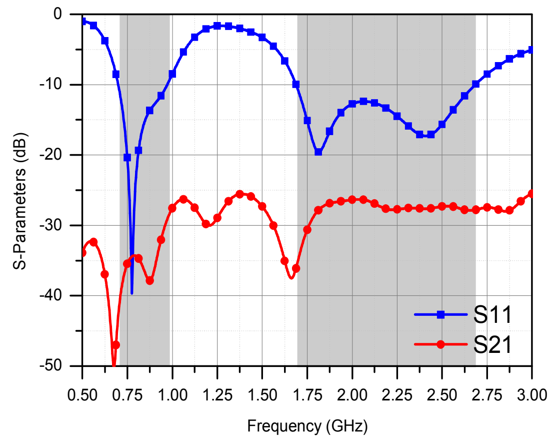
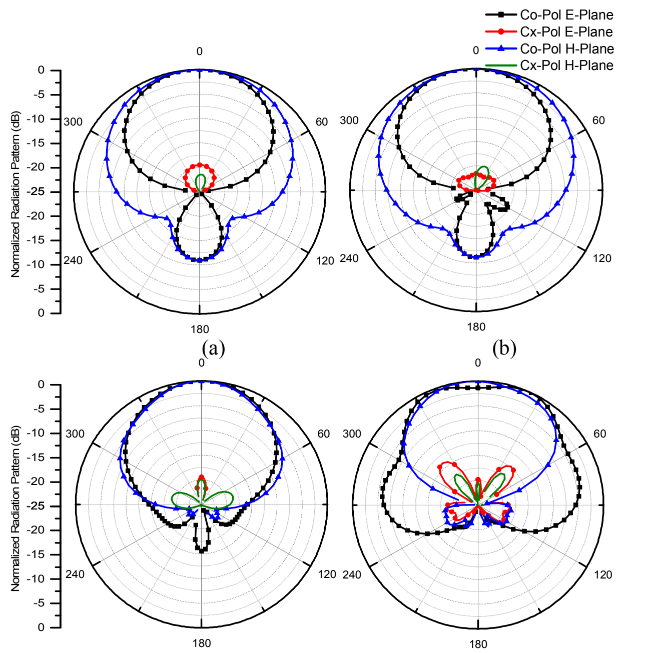


Fig 3. S-parameters of the proposed antenna

The co- and cross-polarized radiation patterns are shown in Fig 4. at the start and end frequencies of each band (700 MHz and 960 MHz for the LB and 1.7 GHz and 2.7 GHz for the UB) in two perpendicular planes: E-plane (XZ-plane) and H-plane (YZ-plane). It is clear that the radiation pattern is stable within each frequency band. The half power beam width (HPBW) and the XPD values are given in TABLE II at each simulated case.

The antenna realized gain in dBi is presented in Fig 5. The gain is 6.3±0.5 dB and 7.4±2 dB for the LB and UB respectively.



(a) (b) (c) (d)

Fig 4. Co- and cross-polarized radiation patterns in E-plane and H-plane at (a) 700 MHz (b) 960 MHz (c) 1.7 GHz (d) 2.7 GHz

TABLE II . HPBW and XPD of The Proposed Antenna

Frequency		700 MHz	960 MHz	1.7 GHz	2.7 GHz
HPBW (°)	E-Plane	75	70	70	80
	H-Plane	100	105	75	80
XPD (dB)		20	22	18	20

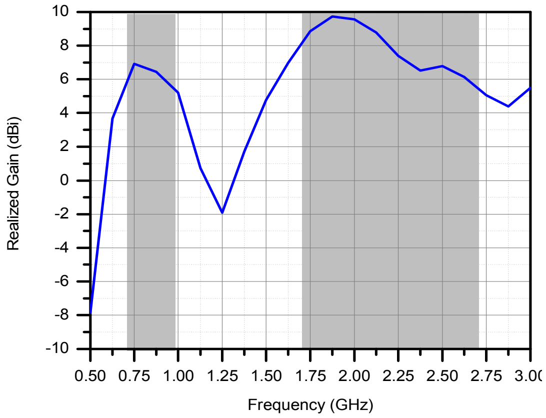


Fig 5. Realized gain of the proposed antenna

TABLE III compares the proposed designed antenna and other dual-band reference antennas in the literature. The proposed antenna has the widest bandwidth in both LB and UB with a relatively small size. It also has the simplest design as it uses PCB manufacturing technology rather than 3D printing and a single element to cover both bands rather than one element for each band.

TABLE III. Comparison of the Proposed Antenna with Dual-Band Reference Antennas

Ref		[11]	[12]	**Proposed Antenna**
BW (%)	**LB**	19.4	31.3	**31.3**
	UB	23.7	44.9	**45.4**
Size (cm^3)		4422	8410	**4840**
Manufacturing Process		3D printing	3D printing	**PCB**
Number of Elements		1 for the LB + 1 for the UB	1 for the LB + 1 for the UB	**1 for both bands**

IV. CONCLUSIONS

A dual-band dual-polarized swastika-shaped antenna has been designed and optimized to cover two different bands simultaneously for mobile communication systems: 700-960 MHz and 1.7-2.7 GHz. The proposed antenna has a stable radiation pattern and high XPD with a good impedance matching for both bands. In comparison to reference designs, the proposed design is much simpler as it uses a single element to cover both bands instead of multiple elements for multiple bands. It also has the widest bandwidth with a relatively small size. The antenna has been made and measurement results will be presented at the conference.

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